

IMPLEMENTATION OF RESILIENT MODULUS IN THE FLORIDA FLEXIBLE PAVEMENT DESIGN PROCEDURE

PROBLEM STATEMENT

The 1986 AASHTO Guide for Design of Pavement Structures (AASHTO, 1986) introduced the resilient modulus concept as a measurement of the pavement roadbed soil strength under dynamic loading. Based on this concept, AASHTO built a framework for a mechanistic design procedure for the pavement structure. Resilient modulus, the elastic modulus under dynamic loading, has been extensively researched in the United States for over 30 years. However, measuring the resilient modulus of pavement materials is still a complex and difficult task because the resilient modulus of soils is a non-linear stress dependent measurement. The determination of the resilient modulus of pavement materials is of vital importance for any mechanistically based design/analysis procedure for pavements.

To be implemented in pavement design, the resilient modulus must be measured by conducting a carefully controlled laboratory triaxial test on a small soil sample. Many highway agencies have been hesitant to implement the test because it is complex and because the results can be influenced by various factors. A more applicable test procedure is needed for the implementation.

Many nationwide studies have been undertaken to find alternate laboratory test methods, and several specifications have already been introduced as the standard procedure for the laboratory measurement of resilient modulus. The Strategic Highway Research Program (SHRP) Protocol P46, AASHTO T294-92 (AASHTO, 1992) and AASHTO T 292-91I (AASHTO, 1991) have been most commonly used in recent years. AASHTO T294-92 appears to be more convenient to perform than the revised procedure AASHTO T 292-91I. However, a more convenient and reliable procedure is still being sought.

Alternatively, other methods are available to estimate the resilient modulus. The most prevalent techniques are (1) back calculation from non-destructive testing (NDT) such as the Falling Weight Deflectometer (FWD) test and (2) estimations from the AASHTO Guide algorithm (AASHTO 1986, 1993). The FWD test is easier to conduct and can provide in-situ layer moduli at a lower cost and with a minimum amount of disturbance, although the values may not always be accurate. No consensus exists as to which procedure provides accurate resilient modulus values for pavement design. However, efforts have been made to compare those moduli in order to establish relationships between them (Daleiden et al. 1994; Akram and Smith 1994; Nazarian et al. 1998; Harold and Killingsworth 1998; Chen 1999; Mikhail et al. 1999; Long et al. 1997). Unfortunately, a well-established relationship has not been found yet.

OBJECTIVES

The primary objective of this study was to implement the 1986 and 1993 AASHTO flexible pavement design procedure (AASHTO 1986, 1993) with the laboratory test procedure for measuring resilient modulus of unbound base/subbase materials and subgrade soils in Florida. Specific objectives include the following:

- to evaluate testing methods for determining resilient modulus on subgrade soils and untreated base/subbase materials
- to correlate laboratory resilient modulus measurements with Limerock Bearing Ratio (LBR) values and FWD test results on subgrade soils and untreated base/subbase materials
- to propose a more convenient and reliable test procedure for the laboratory resilient modulus test procedure
- to conduct a pilot study for implementing the resilient modulus in the Florida flexible pavement design procedure

FINDINGS

Researchers evaluated the relationship between resilient modulus and other bearing characteristics of pavement layers, including LBR (Limerock Bearing Ratio) and FWD back-calculated modulus. An experimental program was undertaken to measure the field and laboratory (both in-situ and optimum compacted conditions) resilient modulus of materials in flexible pavements. The comparisons among these characteristics were made under different conditions.

A feasibility and sensitivity study showed that the laboratory measured resilient modulus under the optimum compacted condition could reflect the actual resilient behavior of granular material in flexible pavements. The flexible pavement design could be based on the resilient modulus values determined in the laboratory. The modified Proctor was recommended for base/subbase materials, but the standard Proctor was recommended for embankment soils.

Researchers proposed a recommended resilient modulus test procedure, adopted mainly from the AASHTO T 292-91I test procedure, that is more convenient and more reliable for determining the laboratory resilient modulus under Florida conditions.

Based on the recommended design procedure, three major pilot projects (SR-54, SR-44 and SR-70) were performed to illustrate the design steps for implementing the resilient modulus in the flexible pavement design procedure.

CONCLUSIONS

Implementing resilient modulus in the Florida pavement design procedure is considered applicable and practical. The conclusions are summarized as follows:

1. Resilient modulus is an excellent measurement under pavement materials service condition in the pavement structure. Measuring the resilient modulus is complex and difficult. However, if the test is properly performed, the resilient modulus measurement is repeatable, reliable, and practical.

2. The AASHTO T 292-91I is recommended for determining the resilient modulus. A resilient modulus test procedure similar to T 292-91I is proposed for Florida conditions.
3. The internal full-length linear variable differential transducer (LVDT) measurement is reliable, practical, and easy to conduct. It is recommended for determining the resilient modulus, although the middle length LVDT measurement is considered more accurate.
4. The resilient modulus under a state of stress with a confining pressure of 2 psi (13.8 kPa) was representative for the resilient behavior of granular subgrade material in flexible pavements.
5. FWD back-calculated moduli were about 1.8 times higher than laboratory resilient moduli for granular materials.
6. No relationship was found to exist between the laboratory resilient modulus and the LBR values.
7. The standard Proctor compaction should be used for measuring the resilient modulus on embankment soils.
8. The flexible pavement structural design is not very sensitive to the change of resilient modulus values when the resilient modulus is higher than 10 ksi (68.9 MPa).
9. Implementing resilient modulus in the Florida pavement design procedure is applicable under the guidelines of the AASHTO Design Guide.

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